RELIABILITY OF TESTING AND ITS DETERMINATION

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Determination of testing reliability on base the analysis errors of measurement of testing parameters are considered. The mistakes of testing first and second kinds and reliability are determined with accounting division of errors on systematic and accidental. The way of optimization of choice limit norm of testing parameter is offered.

Reliability of testing [1] – it is mark of propriety separation of the testing parameters on such that correspond to beforehand set the board of standard or on the contrary – are defective.

The testing parameter is the magnitude of the some physical value which reflects the quality of testing object. It can be temperature, distance, concentration of solution and many other physical units and marks. In nondestructive testing as parameter of testing often is use the line dimension of defect or deviation of thickness, velocity of ultrasound wave spread in testing material and so on.

It is clear that realization of testing process is executing by measurement the magnitude of deviation testing parameter relatively to its nominal significance but it is necessary only for its separation on standard or defective after comparison with admissible magnitude of deviation – the border of norm.

The main characteristic of deviation testing parameter is the law distribution of its density probability. There are twain law of distribution accidental values which can be used for analysis of testing parameters. It is the normal law if this parameter is changing as in side of decrease so and in side of increase relatively the mathematic expectance what equal zero and law of module normal value for parameters what is changing only in one side relatively also zero mathematic expectance. For such laws the dependence of density distribution is equal

$$P(\delta) = \frac{e^{-\frac{\delta^2}{2\sigma^2}}}{\sigma\sqrt{2\pi}}, -\infty < \delta < +\infty, \tag{1}$$

There σ - standard deviation of testing parameter.

The normal law can be applied for distribution of deviation of the thickness or distance relatively its nominal value, for distribution of temperature of testing object, evaluation of deviation any physical parameter relatively beforehand set its level. The law distribution of density probability of module normal value is apply in non-destructive testing for description of such parameter as size of defect of internal structure of testing object’s material. Zero of mathematic expectance deviation of the defect dimensions means being maximum probability of absence defect in testing material.

The errors of the measuring of testing parameters are causing the mistakes referring the result of testing to norm or defective. There are possible to discern the two kinds of mistakes: mistake of the first kind what answer for incorrect referring normal parameter to defective and so undesirable mistake of the second kind when defective parameter have been confessing as correct.

For evaluation of mistakes it is necessary a priori to know the law of density distribution of probability accidental value of testing parameter and error of measuring for significant of testing parameter equal of board of norm. Thereto have to be known the maximum deviation of testing parameter and limit of norm ($\pm\delta_{max} \pm \delta_N$) for normal law and δ_N, - for law of module normal value)

Accordingly so-called rule “three sigma” the evaluation of standard deviation of testing parameter σ normal and module of normal lows of density distribution can be determined as

$$\sigma = \frac{\delta_{max}}{3}, \tag{2}$$

There δ_{max} is limits 99,7% (practically 100%) probability deviation of testing parameters.

The errors of testing parameter measurement have to be separate determined on systematic and accidental. The sum of systematic additive and multiplicative components of error Δ_i can be determine by add up arithmetically:

$$\Delta_{sum.} = \sum_{i=1}^{n} \Delta_i \tag{3}$$

Herewith the multiplicative error take into account only for significant of testing parameter what approximately equal the board of norm.

Systematic error (3) caused to the mistake of testing the kind of which is depend from its sign. Herewith the mistake can arise only for significant of testing parameters directly near to level of board norm. So positive sign of sum systematic error in case nondestructive testing directed to detection defects of internal structure of the materials the mistake of first kind to take place for defects the significant of which is correspond $\delta_N - \Delta_{Sys.} \le \delta \le \delta_N$ (Fig. 1.):

$$P_I = \int_{\delta_N - \Delta_{Sys.}}^{\delta_N} P(\delta) d\delta \tag{4}$$

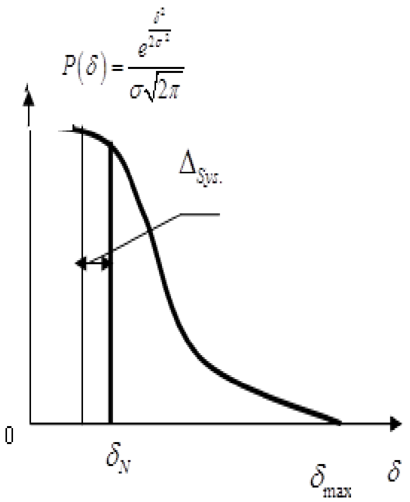

Fig.1. Mistake of the first kind owing of systematic error

When sign of systematic sum error is negative take place the mistake of second kind for significances of parameters $\delta_N \le \delta \le \delta_N + |\Delta_{Sys.}|$:

$$P_{II} = \int_{\delta_N}^{\delta_N + |\Delta_{Sys.}|} P(\delta) d\delta \tag{5}$$

For case of normal law of deviation testing parameter systematic error independently from its sign will cause the mistakes both first and second kinds (Fig.2.). The positive sign of systematic error $\Delta_{sum.}$is reason the mistake of second kind for significant of testing parameters $(-\delta_N - \Delta_{Sys.}) \le \delta \le (-\delta_N)$and mistake of first kind

$$P_I = \int_{\delta_N - \Delta_{Sys.}}^{\delta_N} P(\delta) d\delta \tag{6}$$

$$P_{II} = \int_{(-\delta_N - \Delta_{Sys.})}^{-\delta_N} P(\delta) d\delta \tag{7}$$

The probabilities of mistakes (6) and (7) are considering as dependent evaluations because testing parameter do not be simultaneously belong to both different interval of testing parameters. Thus compatible probability of mistake P_I, P_{II} is equal the sum of its evaluations:

$$P_{mist.} = P_I + P_{II} \tag{8}$$

Consideration influence of accidental errors on the evaluation of mistakes of the testing we begin from determination of sum significance its deviation.

Herewith we have to a count that evaluation of each accidental error is determined as standard deviation what depends from the lawf of its distribution density probability and equal square root from its dispersion.

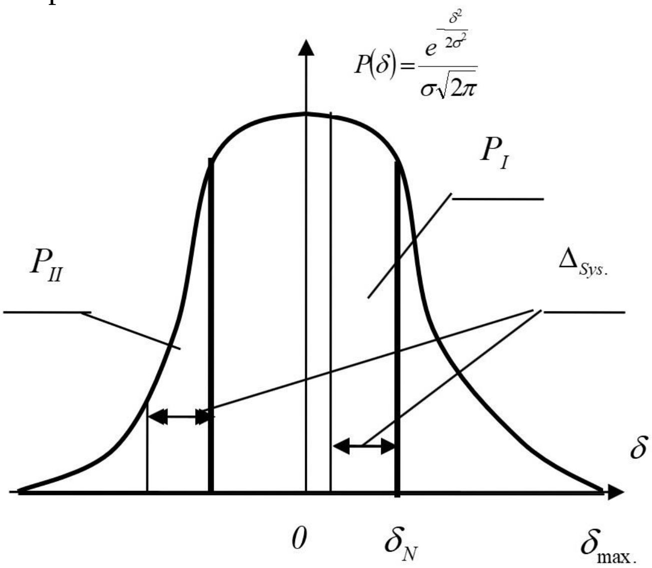

Fig.2. Mistakes first and second kinds account of systematic error

For instance we’ll demonstrate calculation of standard deviation σ_{ADP} of error analog- digital performer (ADP) the accidental error of which in limits $\pm\frac{\Delta_{ADP}}{2}$ (Δ_{ADP}- the lower gradation of ADP in significance of testing value) have of density probability equal$P_{ADP}(\delta) = \frac{1}{\Delta_{ADP}}$:

$$\sigma_{ADP} = \sqrt{\int_{-\frac{\Delta_{ADP}}{2}}^{\frac{\Delta_{ADP}}{2}} \delta^2 P_{ADP}(\delta)\, d\delta} = \frac{\Delta_{ADP}}{2\sqrt{3}}$$

In case if in process analysis of exactness measuring is manifested a several (m) accidental errors the sum of standard deviation is determined as square root from its sum dispersion:

$$\sigma_{sum.} = \sqrt{\sum_{j=1}^{m} {\sigma_j}^2} \tag{9}$$

The standard deviations of errors we regard as row of accidental number what have normal law of density probability. Such allowance is made possible for enable to determine the maximum deviation of sum accidental errors according to above mentioned rule for normal low:

$$\pm\Delta_{Acc.} = \pm 3\sigma_{sum.} \tag{10}$$

Existence only accidental error of measuring become a rise of mistakes both kind. The evaluation of mistakes testing defects in material have been determining compatible possibility of coincidence measuring parameter with its significances $\Delta_N - \Delta_{Acc.} \le \delta \le \Delta_N$, $\Delta_N \le \delta \le \Delta_N + \Delta_{Acc.}$and probability of the error’s sign what equal 0,5. These probabilities are independent therefore compatible evaluation have been corresponding of its multiplication. In such case the mistakes of testing can be determined next equations:

$$P_I = 0{,}5\int_{\Delta_N-\Delta_{Acc.}}^{\Delta_N} P(\delta)\, d\delta \tag{11}$$

$$P_{II} = 0{,}5\int_{\Delta_N}^{\Delta_N+\Delta_{Acc.}} P(\delta)d\delta \tag{12}$$

Now we shall have considered mutual influence the systematic and accidental errors on mistakes of testing when density probability of deviation of testing parameter is corresponds to normal low. If absolute significance maximum deviation of accidental error is less than systematic for example positive error there is presents only mistake of the first kind (Fig.3):

$$P_I = \int_{\Delta_N-\Delta_{Sys.}}^{\Delta_N} P(\delta)\,d\delta + 0{,}5\int_{\Delta_N-\Delta_{Sys.}-\Delta_{Acc.}}^{\Delta_N-\Delta_{Sys.}} P(\delta)\,d\delta \tag{13}$$

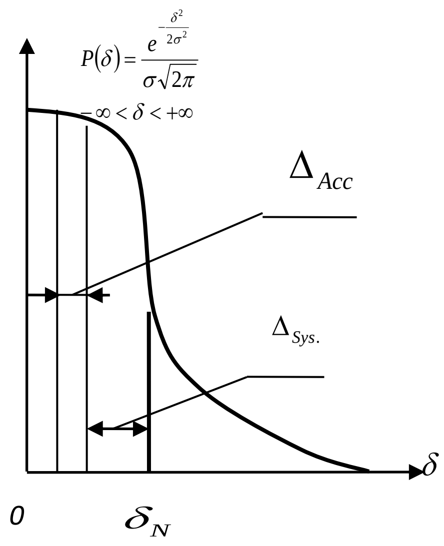

Fig.3. Mistakes of first kind on account of systematic and accidental errors

In case when significance of maximum deviation accidental error exceed the systematic error besides mistake of the first kind (13) there is presents the mistake of the second kind:

$$P_{II} = 0{,}5\int_{\Delta_N}^{\Delta_N-\Delta_{Sys.}+\Delta_{Acc.}} P(\delta)\,d\delta \tag{14}$$

For testing parameter what conformed to normal law of its distribution there are need count more the two similar of mistakes for intervals of testing parameters around another limit of norm:

$$P^1{}_I = 0{,}5\int_{-\delta_N}^{(-\delta_N-\Delta_{Sys.}-\Delta_{Acc.})} P(\delta)d\delta \tag{15}$$

$$P^1{}_{II} = \int_{(-\delta_N-\Delta_{Sys.})}^{-\delta_N} P(\delta)d\delta + 0{,}5\int_{(-\delta_N-\Delta_{Sys.}-\Delta_{Acc.})}^{(-\delta_N-\Delta_{Sys.}+\Delta_{Acc.})} P(\delta)d\delta \tag{16}$$

For such distribution of testing parameters final evaluation of mistake answer the sum of mistakes fist and second kinds as dependent possibilities:

$$P_{mist.} = P_I + P_{II} + P^1{}_I + P^1{}_{II} \tag{17}$$

Then evaluation of authenticity of testing can be determined as a sum of probability.
Certain deficiency the reliability as evaluation of testing is its independence from quantitative characteristic such as limit of norm. It particularly is been showed if maximum of testing parameter deviation is a lot more than limit of norm. We can receive a high evaluation of reliability but all or more part of norm parameters can be confess as defective or on the contrary - can be replace by defective. For exception similar result of testing is need to optimize selection of significance norm limit. For it as additional regulator [2] can be used some coefficient of quantitative quality k which have to be more 0,5:

$$k = 1 - \frac{P_{mist.}}{P_N}, \tag{18}$$

here - $P_N = \int_0^{\delta_N} P(\delta)d\delta$- probability of norm for parameters with distribution of density probability by law module of normal value and for testing parameter with distribution of density probability accordingly normal law - $P_N = \int_{-\delta_N}^{\delta_N} P(\delta)d\delta$.

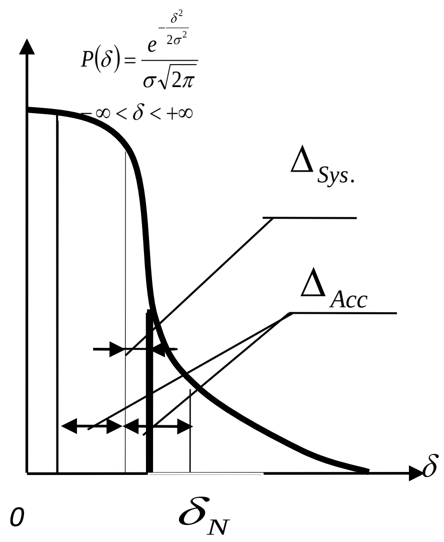

Fig.4. Example of mistakes first and second kinds on account of existence accidental error more than systematic.

Above considered methodic of authenticity analysis can be effective in development the new systems for testing physical and other parameters in different direction of science and technology. In advance set limitation of authenticity make possible to determine the needful technical requirements for each functional cell of system.

Separate determination mistakes of testing both kinds in realizations of nondestructive testing are permit with minimum loss to diminish probability to pass inadmissible defect by correct increasing of mistake the first kind.

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